On the Breeding Habit and Development of *Nereis japonica* n. sp.

BY

Akira Izuka.

Assistant Professor of Zoölogy, Imperial University, Tokyō.

The Lycorid Annelid dealt with in this paper comes very close to *Nereis diversicolor* O. F. Müll., as compared with the descriptions and drawings of the latter given by several authors (Malmgren, Ehlers and Schröder, &c.) and also with the alcoholic specimens* from St. Andrews (Scotland) and from Foxfield in the Dudden estuary (England). However there exist some differences between the two forms, mainly in the arrangement of paragnathi. Thus in the Japanese specimens the paragnathi in the VII. and VIII. division of the proboscis are arranged in one continuous row, while in *N. diversicolor* they are arranged in three or four irregular rows (text-figure 1, A and B.); and moreover the falcate bristles of the former are of a greater magnitude than those of the latter (text-figure 1, C and D.)

The eyes of the former are provided with a distinct lens in each, while there is no lens to be found in those of the latter. The breeding habit of the Japanese worm also differs from that of *N. diversicolor*. I am thus led to consider the former to represent a new species, which shall be named

Nereis japonica n. sp.

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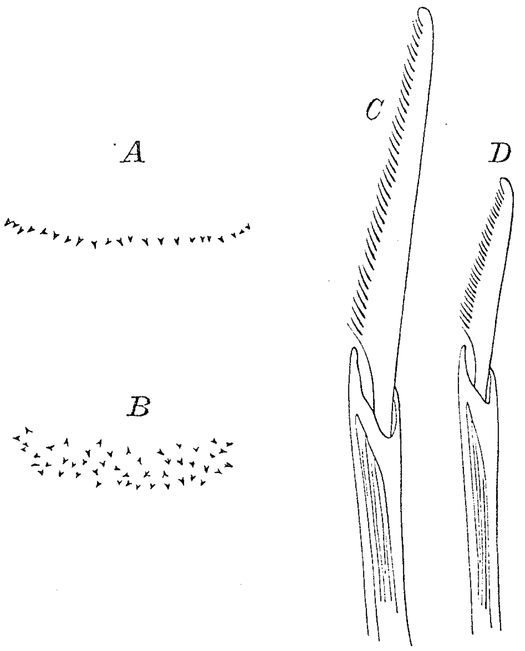
* I beg here to express my thanks to both Professor M'Intosh and Mr. C. Crossland for their kindness in sending me the specimens referred to *Nereis diversicolor* Müll.

Text-figure 1.



A. and B.—the arrangement of paragnathi in the VII. and VIII. division of proboscis; A, *Nereis japonica*. B, *N. diversicolor*. 10/1.

C. and D.—Falcate bristles from the lower rami of parapodium in the middle region of body; C, from *Nereis japonica*; D, from *N. diversicolor*. 390/1.

The worms collected by **Koebl** in the Gulf of Miya and identified with *N. diversicolor* by **Marenzeller**,* are in all probability of the same species as the worm in question, since this so closely resembles *N. diversicolor* that the two might easily be comfounded, whereas indubitable *N. diversicolor* has never yet been met with by me anywhere in Japan.

N. japonica occurs very abundantly in Kojima Gulf (a part of the Inland sea in Okayama Prefecture) and in the rivers emptying into it, and is locally known under the name of "Umi-biiru." The worm in the mature phase is collected in masses and is very extensively used as manure. It occurs also in the Sumida River and in the adjoining parts of the Gulf of Tokyo where it is known by the local name of "Gokai" and is used as bait by anglers through almost all seasons of the year. The species has also been collected by myself and by others in a number of other localities in Japan; thus, in Toba in the Province of Shima; in the Gulf of Miya in Owari; in Shimizu Harbour in Suruga; in Ito in Izu (collected by Mr. **A. Fukuchi**); in Kanazawa in Musashi; in Yokohama; in Matsushima; in Samé Harbour on the east coast of Northern Japan; Lake Busset in Saghalin (collected by

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* **Marenzeller**:—Südjapanische Anneliden I. 1879. P. 14.

Prof. Ijima), &c.

All the material taken from the above mentioned localities, except those from Kojima Gulf, were sexually immature. It is a remarkable fact that in the Sumida River I have not succeeded as yet to obtain a single adult worm of the species, although I had often searched for them. In that river the worm seems to swarm generally once a year in an immature state of development. But in Kojima Gulf it is very easy to get the mature worm in great quantity during the month of December, and also to observe their breeding swarms, and consequently to follow their early development from the egg by artificial fertilization.

With regard to *N. diversicolor*, a species which occurs commonly in European waters M'Intosh* says that the breeding season extends from November till May and that he observed no indication of swarming during those months. The same author further states that he obtained numerous postlarval stages of the species in or near the mouths of the burrows in which the annelid lives.

With these remarks I proceed to record my observations in the following order :—1) on the immature and mature worms, 2) on the fertilization of the eggs and their development, and 3) on the breeding swarms.

I. Observations on the immature and the mature worms.

Immature worms.—The immature worms occur in great abundance between the tide marks along the head of Kojima Gulf and also in the mouths of rivers emptying into it.

The greater part of the gulf is exposed at spring tides, the water then becoming confined to narrow channels leading from the rivers, as shown in the accompanying map of the locality (text-figure 4).

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* **M'Intosh** :—On the Reproduction of *Nereis diversicolor*. (Ann. and Mag. Nat. Hist. 9 series, Vol. 20. No. 117. p. 176, Sept. 1907).

At ebb-tide, the worms are found burrowing in the mud or sand to a depth of a foot or more. In the burrows they move about sluggishly at the most. The entrance into the burrow is usually indicated by a small round hole on the bottom surface. With the flood tide, irrespective of the hour of day, they leave their retirement and creep about on the bottom. They are then very active and voracious, feeding on various aquatic animals and plants. When disturbed they take to swimming. This they do actively, progressing head foremost, by a wave-like movement of the body, which movement starts at the tail and proceeds towards the head.

Scince we have to do with immature growing worms, it is but natural that the dimensions are exceedingly variable; but it may in general be said that they show a length of 60-100 mm. and a breadth of 5-6 mm. The number of segments varies of course according to the size of individuals; in a large one there may be as many as 120 segments.

When alive the body is translucents and generally of a pinkish yellow colour. The gut and blood vessels show themselves plainly through the body wall. The colour of body differs much in shade according to whether the gut is full or empty. The two brown bands exist on the anterior segments but are not at all so conspicuous as in European specimens of *Nereis diversicolor*. In the specimens preserved in alcohol, the colouring matter has dissolved away, leaving only a light brown hue on the anterior dorsal surface of the body.

Mature worms.—In this annelid there is no marked structural difference between the immature and the mature, or terminal pelagic stage except in colour and dimensions. The colour changes with the development of sexual products; it again differs according to whether these are eggs or spermatozoa. The sexual products which fills up not only the body cavity proper, but also its extension into the parapodium greatly distend the body wall; so that fully mature worms generally attain a length of 110-120 mm. and a breadth of 7-8 mm. The number of segments does not exceed 120. There is no indication of any change in the structure of parapodia, in the setae and the eyes. Nor does the posterior region of body undergo shrivelling, as it does in *Ceratocephale oswai.** There can be no doubt, that the persistent condition of parapodia and setae enables the mature worm to swim swiftly through water as in the immature stage.

The swimming worms may be easily captured either with the tow-net or hand-net. The native fishermen who capture them in quantities for manure, employ " pyramidal net," a kind of large bag-net commonly used in Kojima Gulf for the capture of *Mysis*, *Paeneus*, crabs or *Salanx* and other small fishes. The net, as set in frame, is of a pyramidal form, with the mouth at the restangular base of about 2 by 5 *hiro*; the edges of the pyramid measure about 9 *hiro* in length. This net, when set into use, is fastened to two strong poles planted upright in the bottom, the two shorter sides of the mouth being held vertically and the longer sides horizontally. Thus the net is stretched so as to receive the swarm of the worms coming down along with the ebbing water.

The mature worm, after being captured, can be easily kept alive for a week or more in shallow wooden vessels placed at a shaded place and containing a small quantity of the water, taken during high tide, just enough to cover the worms. The water must be changed at least once a day, taking care to remove all the injured worms as soon as possible, without which precaution the water will soon become so filled with discharged sexual products as to be detrimental to the health of the worms. Too much water, as also too much light, induces the worms to motion and thus increases the chance of their receiving injuries to the body.

The sexes are easily distinguishable from the colour of the worms. The females are of a deep green on the dorsal and of a greenish yellow on the ventral side. The males are light greenish yellow dorsally and pinkish white ventrally, blending into a deep pink at the bases of parapodia.

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* **Izuka, A.**—Observations on the Japanese Palolo, *Ceratocephale osawai.* Jour. Coll. Sci. Vol. XVII. Art. 11. 1903.

Sexual Products.—The eggs or the spermatozoa are discharged, while the mature worms are actively swimming near the surface of water.

The eggs sink down gradually to the bottom. They are each surrounded by a thick and transparent gelatinous envelope, so that when found in masses, they are separated from one another by a considerable space. They are spherical in shape, with a diameter of 140-160 μ. In colour they vary from greenish yellow to deep green.

The spermatozoa are found adhering in large numbers to the gelatinous envelope of the ovum. Each spermatozoon consists of an ellipsoidal head and of a long filiform tail. The former is 3.2 μ. long and 1.8 μ. broad. The latter measures 35–40 μ. in length ; it gradually tapers toward the hind end.

2. *On the Fertilization of the Eggs and their Development.*

Artificial fertilization by bringing together the eggs and spermatozoa taken from mature worms can easily be effected, provided with precaution be taken to keep the water at a constant temperature (about 15°c) and its salinity the same as at high tide in Kojima Gulf.

About ninety minutes after fertilization, the first polar body is extruded ; the second follows about thirty minutes later.

The cleavage of the egg is total and unequal. The first cleavage takes place about three hours after fertilization (text-figure 2, A.) ; the second is accomplished about fourty minutes later (text-figure 2, B); the third is completed (text-figure 2, C) about five hours and a half after fertilization. The cleavage process agrees in general with that described by **E. B. Wilson**[*] for *Nereis limbata* ; only it seems to proceeds much more slowly.

Ciliated embryos first appear about 40 hours after fertilization ; 4 or 5 hours after that the embryos are seen swimming about very actively in the vessel containing them. They then show a marked positive heliotactic nature, so that the water in the vessel may now be easily changed by means of a siphon.

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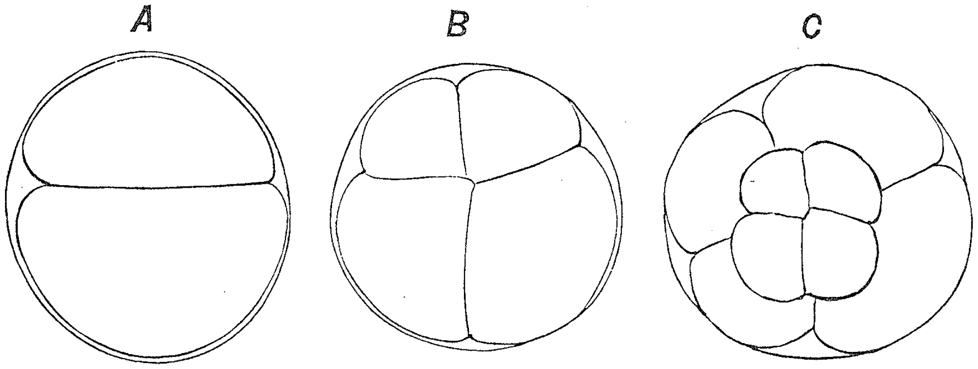
[*] **Wilson, E. B.**—The Cell-liniage of *Nereis*. Jour. of Morphology Vol. VI. 1892.

Text-figure 2.



Early stages of segmentation.

A.—Completed two-celled stage seen from the lower pole. 140/1.

B.—View from the upper pole after completed second cleavage. 140/1.

C.—View from the upper pole after completed third cleavage. 140/1.

(Polar bodies are not indicated. All the figures are drawn from the living egg.)

About 90 hours after fertilization the setae begin to appear.

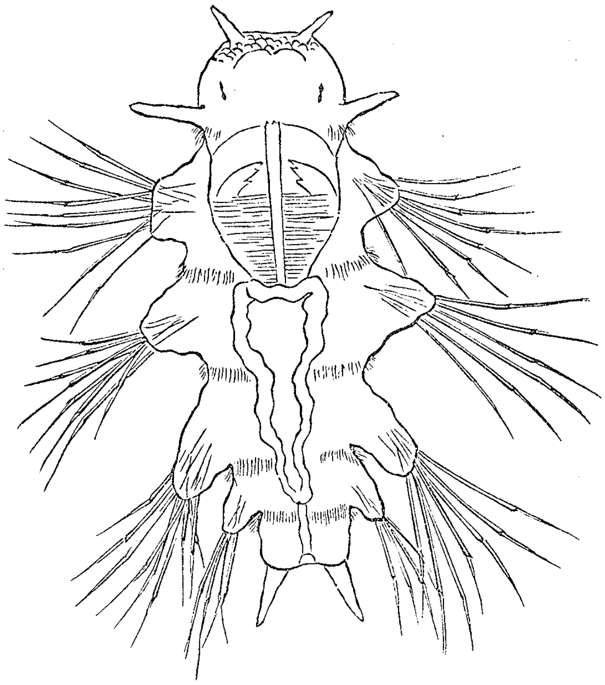
One of the embryos of about 9 days age is represented in the text-figure (3); it is provided with four pairs of setigerous parapodia, a pair of tentacles, a pair of tentacular cirri and a pair of short anal cirri. The two pairs of the "anlagen" of the eyes are distinctly seen on the postero-lateral parts of the head; a pair of jaws, each with three teeth, may also be seen already in this stage of development.

The embryos, at about this stage of development, begin to sink down gradually through the water, in which they have been reared; and about two days later, most of the embryos have sunk down to the bottom to enter into the sedentary life.

3. *Observation on the Swarming.*

With respect to the swarming habit of the mature worm, it has long been known from the experience of fishermen in the locality that the swarming occurs during the month of December, usually in one period.

Text-figure 3.



The embroy of 9 days old, with 4 setigerous segments. 140/1. *Nat. Size.*

lasting a few days ; that the period begins on the night just before the day of the new or the full moon in the middle or the latter part of the month mentioned ; that it invariably takes place in the mid night just after the flood-tide ; and further that very rarely it occurs in two periods, close to the consecutive new and full moons.

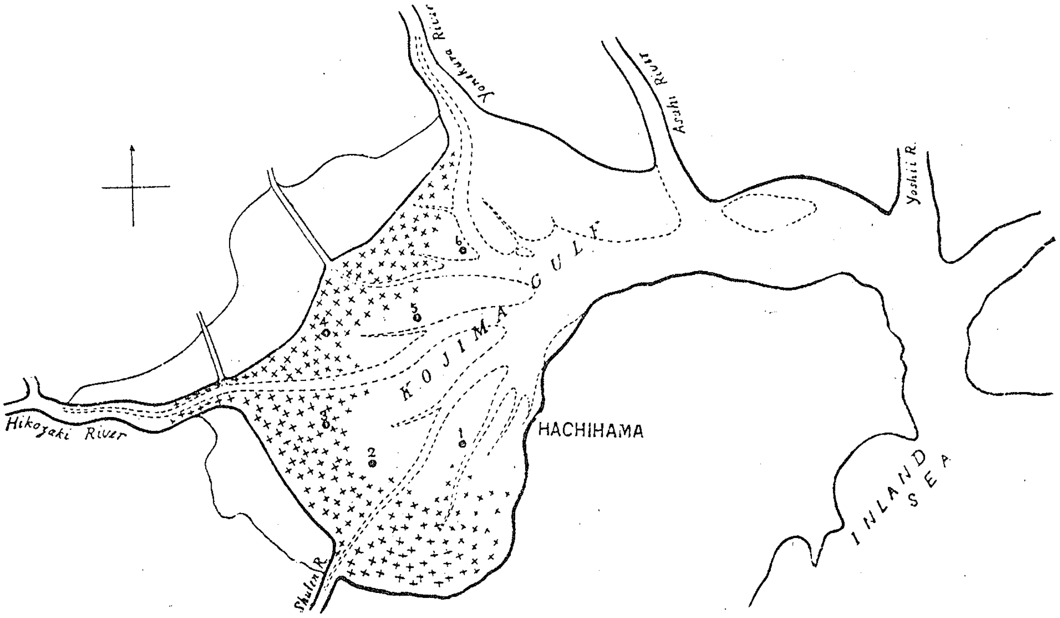
After making observations for myself, I am convinced of the general accuracy of the fishermen's predictions as to the time when the swarming should take place.

The first swarming of the year 1906 occurred on the night of December 15th. On that day the worms that swarmed out were observed to be very few, but on the following day (the day of the new moon) the swarm proved to be one of the largest of that year.

For an illustration I may describe the swarming of that day, *i.e.* the 16th December, 1906. Before proceeding further, it would be well to give some notes about the place in which the swarming occurs. As Kojima Gulf (text-figure 4) stands in connection with the open Inland Sea, by a narrow channel, the hours of the flood and ebb tide differ very much from those on the open sea coast of the same longitude in the south of Shikoku; thus in Kojima Gulf, the flood occurred at 11.40 p.m. on December 16th, 1906, while it should have taken place in the outer sea at about 6.30 p.m.; and in Tokyo at 4.43 p.m. on the same day.

The fishing for the worms are done at six stations, the positions of which are denoted by numerals in the annexed map (text-figure 4) and which, according to long experiences of the fishermen, should be the most advantageous for the work and so remain fixed from year to year. A number of the fishing boats assemble at each station and sets the "pyramidal nets" at work. Station No. 1, as being the nearest to Hachihama where I have stayed, was the one whither I repaired, in good time to see the beginning of the swarming. The fishing boat I was in was manned by three men and was provided with a lantern, a "pyramidal

Text-figure 4



The Map of Kojima Gulf.

1-6 denote the stations where the poles for the "pyramidal nets" are planted. The marks × denote the area inhabited by the worms. The dotted lines indicate the boundaries of the mud flat exposed at the spring-tides.

net," two hand-nets and such other utensils as might be required for observing, capturing and preserving the worms. About eleven in the night, the place was reached. More than half an hour was spent in the task of preparing for the worm-fishing. Three more boats assembled at the station, thus making a party of four boats each with a lighted lantern and a "pyramidal net" planted on the bottom. The four nets were so set that their mouths lay almost in a streight line. About a quarter past twelve (0.15 a.m. 17th, Dec.) I have observed the first swimming worms. About fifteen minutes later, the worms had become so numerous that I could scoop up a number at a time with the hand. The swarm was thickest after about three quarters of an hour from the beginning. All the worms swam about rapidly, somewhat after the manner of eels, darting in all directions. It then almost appeared that the worms in a sheet had covered up the surface of the water. I ascertained that the swarm reached to a depth of five or six feet from the surface. About an hour and a half from the beginning, the worms began to gradually disappear, and after about half an hour (at 2.15 a.m. Dec. 17., about two hours after the beginning of the swarming), there was no longer a single worm found swimming. The work was now over, but the boats stuck to the bottom on account of the low-water and had to await the return of flood in order to be able to move off. At about nine o'clock in the morning of the 17th, all the boats were at home again. Some of them had alone captured over 160 tabfuls* of the worms. The entire catch on that night at the six stations, was estimated at no less than 2,620 tabfuls.

The above account, except so far as concerns the hours of day, may in general be considered to hold good for all the occasions when the swarming takes place in large numbers. It seems certain that a large part of the swarms is carried off into the sea by the ebbing tide.

The results of my observations on the swarming in the year 1906 may be tabulated as follows:

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* A tabful equals in volume to about 17 liters.

Date and phase of moon.	Time of flood at night.	Hour and duration of swarming.	Swarming worms.
Dec. 15th.	10.0 p.m.	About 11.30 p.m.	very few
„ 16th, New Moon.	11.40 p.m.	*	*
„ 17th.	*	0.10–2.0 a.m.	Abundant.
„ 18th.	0.20 a.m.	1.0–3.0 a.m.	Abundant.
„ 19th.	1.0 a.m.	about 3.0 a.m.	Few.
„ 20th.	1.45 a.m.	——	None.

In the next following year (1997), **Mr. Iwaki** of Hachihama kindly undertook to make the observations at my request. For that I beg here to express my thanks to him. He could make observations only in the night of Dec. 20th (the day of full moon). In that night the flood was at 11.30 p.m.; and the swarm was thickest at about 1.0 a.m. of the 21st. The night's catch by four boats at station No. 1 amounted to only 80 tabfuls; and the total catch at the six stations by sixteen boats, to 277 tabfuls. Adverse circumstances of weather prevented **Mr. Iwaki** from making further observations on other days in the swarming season.

In conclusion I beg to offer my thanks to **Prof. Ijima** for the aid rendered me in the preparation of this paper.

February 18th, 1908.